SORGHUM MANUAL

for the Philippines

TABLE OF CONTENTS

	Page
The Sorghum Plant	
Origin and Distribution	1
Nature and Characteristics	1
Grain sorghums	1
Forage sorghums	1-2
Grass sorghums	2
Broomcorn	3
Adaptation	3-4
Uses	
Grain	4-5
Forage	5-6
Grass sorghums	6-7
Botany	7-8
Roots	8
Stems	8
Leaves	8
Flowers	9
Grain	9
Genetics	9-10
Sorghum Varieties and Hybrids	
Varieties	10-11
Hybrids	11
Sorghum Cultural Methods	
Land Preparation	12
Method of Seeding	12-13
Rate of Seeding	13-16
Time of Seeding and Crop Sequences	17-18
Cultivation	18-20
Water Relations	
Dryland	20
Irrigation	20-21
Fertilization	21-22
Weed Control	22
Insect Control	23-25
Disease Control	26
Other Hazards	26-27
Sorghum Grain Management	
Harvesting	28
Drying	28
Storage	29
Estimates of Costs and Returns	29-31
References Cited	32

THE SORGHUM PLANT

Origin and Distribution

Sorghums have been known to mankind for many centuries. They are considered to have originated in Africa and in Central Asia. Now sorghums are distributed from the equator to the 50th parallelogram around the world.

Nature and Characteristics

The sorghums are members of the grass family, Graminae, as are corn, rice, and sugarcane. There are several types of sorghum which have been grouped into the following classes:

Grain sorghums - These include two kinds. One kind consists of the open-pollinated (pure-line) varieties of which the seed may be saved and replanted. The second consists of the more recently developed single-cross hybrids of which it is not advisable to keep seed for replanting. The latter are very popular, having taken over virtually all the acreage in the U.S., and they are commonly referred to as sorghum hybrids. Both of these kinds of sorghums may be short stature plants growing from 1 to 2 meters in height, or they may be taller, but they are grown primarily for the grain. The stalks may be juicy or pithy, but they are usually not sweet.

Forage sorghums - Again there are two kinds available, the varieties and the hybrids. The forage types are usually tall, growing from 2 to 3 meters in height. They were developed for their ability to produce high tonnages of forage which may be used as ensilage or roughage for livestock. Some kinds

produce a heavy crop of grain as well. The stalks of the varieties are juicy and sweet. The sugar content of the juice often exceeds that of sugarcane, and it can be made into sugar and/or syrup. Some of the forage hybrids, however, do not have either juicy or sweet stalks, and therefore produce a forage of lower quality.

Grass sorghums - This class consists of the sudangrass varieties, and the more recently developed hybrids made by crossing grain or forage sorghums with grass sorghums. The resulting hybrids are intermediate in type between the two parents, but they possess more of the grass characteristics. These latter types are usually labelled as sorghum-sudangrass, or sorgo-sudangrass hybrids. True sudangrass hybrids are now becoming available also.

The grass sorghums have slender stalks, are leafy, tiller profusely, and regrow quickly after clipping. They are commonly used for grazing and for hay.

Wild species of sorghum fall in this group. In the Philippines the most common wild species appears to be Sorghum propinquum, a diploid form having 10 pairs of chromosomes. It has long, harsh lanceolate leaf-blades with a yellow midrib and saw-toothed margins. The panicles are open, the glumes awnless, the caryopses very small, and covered with dark glumes. The plants have underground stems (rhizomes), being the only diploid form known to have them.

Broomcorn - A more appropriate name would be "broomsorghum." The crop is grown for the brushy panicles which are used for making brooms in Europe and America, and the crop could be grown in the Philippines for the same use. Present types are of little value for grain or forage.

Adaptation

Sorghums are well adapted to warm climates. Although they are indigenous to the tropics, they are now grown far into the temperate zones during short warm seasons. The alternation of wet and dry seasons lends well to sorghum production. The crop can be planted during the wet season and allowed to mature during the dry season. This allows for proper maturation and drying of the grain without losses due to weathering of the grain in the field or damage in storage.

Sorghum plants are generally considered to be able to withstand more extremes of climate and soil than corn. Sorghum produces profitable yields of grain on the margins of the corn belt in the United States where corn is not profitable because of inadequate moisture. Sorghums become more or less dormant during periods of moisture shortage and resume growth when moisture becomes available, again. They do, however, produce their best yields with adequate moisture. Sorghum will tolerate excessive moisture better than will corn, but again best results will be obtained with good drainage. Sorghums

will tolerate more heat and high temperature than corn as evidenced by their production in the southwestern part of the U.S. where corn for grain is not profitable. Neither corn nor sorghums grow appreciably when the temperature goes below 60°F. Sorghums thrive from sea level to 5000 feet in soils ranging from light sandy soils to heavy clay soils with pH values ranging from 4.5 to 8.5. During a drought, however, sorghums in sandy soils usually survive better than those in clay soils.

Uses

Grain - The largest usage of sorghum grain in the western hemisphere is for livestock and poultry feed. As a feed-grain, sorghum compares favorably with corn, having slightly more protein and slightly less fat on the average. The yield of carbohydrates is about equal for the two grains. When feeding sorghum grain to cattle, sheep, and swine, it should be ground in order to increase the rate and efficiency of assimilation by the animal. For chick mash, broiler mash, or layer mash the grain should be ground, also. But for "scratch" feed the grain may be cracked or even fed whole, since the poultry gizzard is capable of "grinding" the grain. Sorghum grain, like corn, is a carbohydrate feed, and it will need to be supplemented with concentrates as well as with roughage. It is especially important to supply certain amino acids which are abundant in the protein fraction of soybean meal, cotton

seed meal, and fish meal, in order to formulate a balanced ration and to get rapid and efficient grains. Most Sorghum varieties and hybrids are lacking in carotenoid pigments (Vitamin A precursor) as is white corn. Brown grain is often less palatable than red or white grain.

In the areas of the world where sorghum grain is used for human food, the white grain is much preferred, except for brewing when dark grains are preferred apparently for their astringent quality.

Starch may be milled from sorghum grain and substituted in part for wheat flour in baking bread, biscuits, cakes and cookies. The starch is used industrially in wallboard, sizing, adhesives, and oil well drilling muds. The starch can be converted to dextrose and used in confections or canning. Glutinous sorghum starch can be substituted for cassava starch in Tapioca. Sorghum grain has been used to produce industrial alcohol, and for brewing. Many other industrial uses are known.

Forage - Sorghum forage consists of all the above-ground parts of the plant, and usually contains less than 20 percent of grain by weight. Sorghum forage contains slightly less digestible nutrients than corn forage but it is more palatable and the yields are higher. Dry sorghum forage contains slightly above 50 percent digestible nutrients which consist of 8 percent protein, 2.5 percent fat, and 45 percent nitrogen-free extract.(2)*

*Numbers in parentheses refer to references cited.

Sorghum silage is produced by chopping the whole plant and ensiling the resulting material with or without the addition of molasses or other "sweeteners". Best yields are obtained when the grain has reached the hard dough stage. Best results from fermentation are obtained when the moisture content of the whole plant is at or below 70 percent before ensiling. Sorghum silage when properly ensiled and sealed may be stored almost indefinitely. It may be used with supplements to feed dairy and beef cattle. Freshly chopped forage sorghum may be fed directly with or without supplements, when facilities for ensiling are not available.

Dry sorghum forage either shredded or not may be used with a little protein supplement to maintain livestock in good condition through periods of drought or excessive moisture. Shredding or grinding usually results in better utilization.

Certain varieties of forage sorghum when pressed yield juice that can be made into syrup. The juice from other varieties lends itself better for making sugar.

Grass sorghums - Recently new types of sorghum forage have become available. These new types are intermediate between forage sorghums and sudangrass. They are usually more productive than sudangrass, but somewhat lower in quality of forage. They are sown thickly and either grazed off or clipped for hay at the booting stage. Rapid recovery results in the production of several crops from one seeding. Sudangrass varieties react quite similarly, but often do not recover as quickly nor as often.

Caution should always be exercised in grazing young or ratooned sorghum plants because of the possible presence in the plant of prussic (hydrocyanic) acid. Cattle (rhumenants) may be poisoned from feeding upon the plant when this acid content is too high. In the tropics the sorghums behave as perennials, and following harvest of the grain or forage, the plant continues to grow. When the plant is mature, the prussic acid content is lowest. It is highest in new growth following harvest or drought. The plant, after it is cut and cured or ensiled, is safe to feed. Also, the forage from pure sudangrass varieties, is considered to be safe from prussic acid poisoning.

Botany (3)

Sorghum, Sorghum vulgare Pers., is a large grass of many varieties. Because of its great height it was named sorghum from the Latin word "surgo" which means "arise."(2) Although many of the varieties indigenous to Africa and Asia are very tall, mutations have made possible the selection of very dwarf varieties. There is an extremely wide range of characteristics in the species not only for height but for other plant and seed characteristics. The cultivated forms have been grouped into type-classes which are becoming less and less distinct among present improved varieties and hybrids because of inter-crossing and the selection of new forms combining characteristics of more than one type. Broomcorn, sudangrass, and some of the forage varieties have remained somewhat true to their type-class

descriptions.

Wild sorghum species are known throughout the world. In the Philippines Sorghum propinquum seems to be the dominate one.

Roots - The roots of sorghum are fibrous, adventitious, and develop many laterals. Sorghum has twice as many roots per unit of leaf area as does corn. This is one reason sorghum is drought resistant.

Stems - The stems are solid with grooved internodes alternating from side to side between nodes. The stems may be juicy or pithy, and sweet or non-sweet. Juicy stems are associated with cloudy leaf mid-ribs, while pithy stems are associated with white mid-ribs. There is an adventitious bud at each node, and at the base of the plant where the nodes are close together, these buds often initiate new stems when the old one is cut off. The length of the internodes determines the height of the plant. Varieties of the same maturity, although vastly different in height, have the same number of nodes.

Leaves - The leaves appear alternately on the stem. The leaf sheaths are long and overlap in dwarf varieties. Wide leaves are borne on large stems, and narrow leaves on small stems. The stomata of sorghum leaves are about two-thirds the length of those of corn, but are enough more numerous so that the stomatal area per unit of leaf of the two crops is about the same. Careful studies have shown that about three days are required to produce each leaf of sorghum. All leaves from the seedling stage on through must be counted.

Flowers - The inflorescence of sorghum is a panicle that is borne at the top of the stem. It is usually called a "head" and varies from compact to open. Spiklets having both male and female parts within the same flower are borne in the branches of the head. Seeds form between the glumes which may have awns. The glumes may be black, red, brown, or straw colored, and they may cover the seeds partially or completely. Sorghum flowers bloom in the early morning starting at the top of the head and progressing downward daily until blooming is completed in 4 to 6 days. Sorghums are largely self-pollinated, but they will outcross as much as 5 to 10 percent.

Grain - The grains of sorghum are smaller than those of corn, and vary in size from variety to variety so that a kilogram of grain may contain from 20,000 to 65,000 individual grains. Seeds may be white, yellow, red, or brown. Their composition usually shows more protein and less fat than corn. The largest portion of the kernel consists of the carbohydrate material in the endosperm, usually about 65 percent. This starch has about 23 percent amylose in most varieties. Glutinous varieties have all amylopectin and no amylose. Most varieties are practically devoid of carotenoid pigments (Vitamin A precursor), but breeding programs to incorporate these have already produced some varieties.

Genetics - Sorghum has 10 pairs of chromosomes,as does corn, Many of the genes controlling plant characteristics have been studied. The genes controlling the major differences among the vast array of known forms of sorghum are largely simply inherited.

And since so many of the known forms will cross-pollinate readily, there is some tendency to group many of the present species into a single specie.

SORGHUM VARIETIES AND HYBRIDS

Since sorghums are considered to have originated in the tropical areas of Africa, there should be no serious problem in finding good sorghums for the Philippines. From preliminary observations, it is expected that many of the numerous varieties and hybrids which are available will perform well.

Varieties

Good seed of the open-pollinated pure-line varieties has become less plentiful with the advent of the hybrids, but small amounts, at least, of seed of almost all the varieties ever developed are still available. Some of these varieties compete favorably with the hybrids. The Bureau of Plant Industry has evaluated a limited number of grain and forage sorghum varieties in both wet and dry seasons at several locations.* The University of the Philippines, College of Agriculture has evaluated sorghum varieties, also, and has small increases of three promising varieties.** On the average, however, the sorghum hybrids may be

*Solpico, F. Oral Communication. Philippine Republic Bureau of Plant Industry, Agronomy Section, Manila. November, 1966.

**Gomez, A. Oral Communication. University of the Philippines, College of Agriculture, Plant Breeding Section, Los Baños. December, 1966.

expected to produce 20 to 30 percent more grain than varieties of the same maturity class, making the additional investment in seed well worthwhile.

Hybrids

A number of commercial seed companies in the United States and some other countries are producing a great many sorghum hybrids each with slightly different characteristics. State and federal experiment stations also have released a goodly number of hybrids. In fact, there are so many on the market that it is often difficult for the grower to make a choice.

Sorghum hybrids are produced in isolated seed production fields by interplanting rows of the seed parent and pollen parent. Most of the hybrid sorghum seed produced is the result of a single cross. A few are produced by means of a three-way cross. Sorghum differs from typical corn in that both male and female parts of the flower are borne within the same floret in the head rather than being separated in the tassel and ear shoot. Therefore, the practical production of hybrid sorghum seed was possible only after the discovery and incorporation of a cytoplasmic genetic characteristic causing the male part of the flower of certain lines to be non functional. Such lines become the seed parent in production fields, and seed harvested from these rows is sold for the production of sorghum hybrids.

SORGHUM CULTURAL METHODS

Land Preparation

Cultural practices for sorghum are similar to those required by other row crops such as corn. A seedbed should be well prepared by use of a moldboard plow or large diameter disc plow followed by disking and harrowing. The seed bed should be firm and the soil surface mellow. Sorghum plants are small and do not compete with weeds well until they are 3 to 4 weeks old.

Method of Seeding

On dryland or for sprinkle irrigation the crop may be sown with a lister or with a surface planter. For furrow irrigation, the crop may be sown with a surface planter, or may be sown on ridges in single or multiple rows. When sown on the surface, irrigation furrows are opened up between the rows at the time of the second cultivation or when the plants are 30 to 40 cm. tall and able to shade the soil. When ridges or "beds" are established for the seedbed, 1 to 4 rows may be sown on the bed leaving the furrow open. Some producers sow seed in rows in the furrows as well as on the bed. Either method can be accomplished with a grain drill by planting solid or by stopping some of the holes. Fertilizer applied before seeding or at the time of seeding should be put underneath or toward one side of the seed to avoid direct contact. The seeds should be covered from 2 to 5 cm. deep, and they will germinate

most rapidly if firmed into the soil and then covered with soil that is firmed lightly. Sorghum seedlings are not strong and may have difficulty emerging from a compacted or crusted surface layer, especially as it becomes dry.

In the absence of machinery, the carabao and plow may be used to open furrows 1/2 meter apart or wider and deep enough to enable the following operations:

(1) Spread fertilizer in the bottom;

(2) Cover the fertilizer with 5 to 7 cm. of soil;

(3) Drop the seeds;

(4) Firm the seeds into the soil; and

(5) Cover them with 2 to 5 cm. of soil by harrowing.

Rate of Seeding

The appropriate rate of seeding will vary with the yield. A heavy yield will require more plants per hectare than a light yield. Environmental conditions of soil and climate appear to be very favorable for sorghums in the Philippines On chis assumption any given level of production (within limits) may be achieved simply by establishing sufficient plants and supplying them with adequate moisture and nutrients In Table I available moisture has been used as a basis for dividing expected grain yields into three categories, namely, rainfed marginal, rainfed adequate, and irrigated. These are shown in the first column In the third column is shown a range of theoretical grain yields from 1000 to 12000 kg./ha. Using the 5000 kg./ha level of

TABLE I. Sorghum Guide for Plant Population and Fertilization Based on Expected Yield

Moisture	Expected Yield Per Ha. Cav./Ha. (1)	Expected Yield Per Ha. Kg./Ha.	Seed Kg./Ha. (2)	Plants Per Ha. (3)	Fertilizer Kg/Ha N	Fertilizer Kg/Ha P_2O_5 (4)	Fertilizer Kg/Ha K_2O (4)	Fertilizer No. of 50 Kg. Bags /Ha. 14-14-14 (5)	Fertilizer No. of 50 Kg. Bags /Ha. Urea (or) (5)	Fertilizer No. of 50 Kg. Bags /Ha. Am. Sul.
Rainfed Marginal	18	1000	1.2	27,000	25	14	14	2	1/2	1
	36	2000	2.4	54,000	50	28	28	4	1	2
	55	3000	3.6	81,000	75	42	42	6	1-1/2	3
Rainfed Adequate or Partially Irrigated	73	4000	4.8	108,000	100	56	56	8	2	4
	91	5000	6.0	135,000	125	70	70	10	2-1/2	5
	109	6000	7.2	162,000	150	84	84	12	3	6
	127	7000	8.4	189,000	175	98	98	14	3-1/2	7
Irrigated	146	8000	9.6	216,000	200	112	112	16	4	8
	164	9000	10.8	243,000	225	126	126	18	4-1/2	9
	182	10000	12.0	270,000	250	140	140	20	5	10
	200	11000	13.2	297,000	275	154	154	22	5-1/2	11
	218	12000	14.4	324,000	300	168	168	24	6	12

(1) Based on 55 Kg./cavan with 10% moisture content for storage.

(2) Planting rate based on 28,000 seeds per kilogram

(3) Based on 20 per cent loss from failure to germinate and other causes.

(4) Rule of thumb = 25 Kg. N + 14 Kg. P_2O_5 + 14 Kg. K_2O per hectare for each ton (1000 Kg.) expected yield.

(5) Complete fertilizer (14-14-14) at time of planting. Urea or ammonium sulphate side dressing four weeks after planting or when plants are 40 to 50 cm. tall.

production as an example, it was estimated that 6 kg./ha. of seed should be sown in order to get 135,000 plants/ha. established. With seed that has 28,000 grains/kg., 168,000 seeds will have been sown However, at least 20 percent of these will fail to produce a plant because of failure to germinate or other reasons, resulting in an estimated population per hectare of 135,000 plants. Similarly other combinations are suggested for yields lower and higher than the example. For seed of larger or smaller size adjustments can be made in the kg /ha. of seed sown to get a desired plant population.

Sorghum plants are capable of compensating to some extent for plant population. When the plants have more space, they will produce larger heads than when they have less space in which to grow. Table II may be used as a guide for determining how close together plants should be in the row on the average at a given row width in order to achieve a desired plant population. For instance, to follow through with the previous example of 5000 kg /ha. and 135,000 plants, in rows 100 cm. (1 meter) apart the plants in the row should average one every 7.4 cm If the rows are half as far apart or 50 cm., the plants in the row should average one every 14.8 cm. or twice as far apart. Similarly, other combinations of row and plant spacings can be determined for this and other plant populations

Table II may also be used to calculate the plant population in the field after it has been established This information may be helpful in deciding on the optimum plant

TABLE II. Sorghum Plant Populations With Certain Combinations of Row and Plant Spacings

Moisture	Expected Yields Cav./Ha. (1)	Expected Yields Kg./Ha.	Seed Kg./Ha. (2)	Plants Per Ha. (3)	Distance Between Plants (Cm.)	Distance Between Rows (Cm.) 100	90	80	70	60	50	40	30	20	Distance Between Plants (Cm.)
Rainfed Marginal	18	1000	1.2	27,000	37.0	41.2	46.3	52.9	61.7	-	-	-	-		
	36	2000	2.4	54,000	18.5	20.6	23.1	26.5	30.9	37.0	-	-	-		
	55	3000	3.6	81,000	12.3	13.7	15.4	17.6	20.6	24.7	30.9	-	-		
Rainfed Adequate or Partially Irrigated	73	4000	4.8	108,000	9.3	10.3	11.6	13.2	15.4	18.5	23.1	-	-		
	91	5000	6.0	135,000	7.4	8.2	9.3	10.6	12.3	14.8	18.5	24.7	-		
	109	6000	7.2	162,000	6.2	6.9	7.7	8.8	10.3	12.3	15.4	20.6	-		
	127	7000	3.4	189,000	5.3	5.9	6.6	7.6	8.8	10.6	13.2	17.6	-		
Irrigated	146	8000	9.6	216,000	4.6	5.1	5.8	6.6	7.7	9.3	11.6	15.4	-		
	164	9000	10.8	243,000	-	4.6	5.1	5.9	6.9	8.2	10.3	13.7	-		
	182	10000	12.0	270,000	-	-	4.6	5.3	6.2	7.4	9.3	12.3	18.5		
	200	11000	13.2	297,000	-	-	-	4.8	5.6	6.7	8.4	11.2	16.8		
	218	12000	14.4	324,000	-	-	-	4.4	5.1	6.2	7.7	10.3	15.4		

(1) Based on 55 Kg./cavan with 10% moisture content for storage.

(2) Planting rate based on 28,000 seeds per kilogram.

(3) Based on 20% loss from failure to germinate and other causes.

population for a situation in which the environmental factors differ from those described.

Time of Seeding and Crop Sequences

It would appear from results obtained by the Bureau of Plant Industry that grain yields from sorghums may be expected to be higher in the dry season than in the wet season. The reverse may be true for the forage types. Difficulty may be encountered getting seed set in the wet season, and in maturing and drying sorghum grain. Hence, it is deemed advisable to plant grain sorghums so that they will bloom during a period of less frequent rain and mature during the dry season. Such a practice could be followed in Central and Northern Luzon on unirrigated land by sowing grain sorghum immediately after rice harvest in October and November. Where partial irrigation is available, grain sorghum could be sown even later and supplied with irrigation water one or more times, especially during booting and filling. In the western Visayas land not producing sugarcane, might be used to produce a crop of corn or forage sorghum during the wet season, and a crop of grain sorghum during the dry season. On southern Mindanao where the rainfall is evenly distributed throughout the year grain sorghum could be sown at any time. Experience will probably determine the best planting dates within a few years. Similarly, the optimum time of seeding in areas not mentioned will be determined by experience.

Forage and grass sorghums probably can be sown and produced in the wet season, since the primary objective is not the grain. They could be grazed, fed green chop, or ensiled.

The period of time required from seeding to harvest of sorghum in the Philippines appears to be somewhat shorter than in the United States. Hence, varietal or hybrid descriptions accompanying seed from that source should be viewed with this in mind. Hybrids requiring 105 to 120 days in the United States will apparently mature in 90 to 100 days in the Philippines. Ninety-day hybrids mature in as few as 75 days. This may not be a general rule, because some varieties are sensitive to photoperiod and some are insensitive. But in general sorghums are a short-day plant and short days and long nights tend to speed up maturity, especially when the temperature requirements of the plant have been met.

Suggested times of seeding for sorghum are summarized in Table III for certain areas of the Philippines.

Cultivation

Timely cultivation is of utmost importance. Weeds use moisture and nutrients that should be available for the crop. Where sorghums are sown in wide rows, some form of cultivation of the soil for control of weed growth will be necessary. Regular row-crop equipment may be used. When narrow rows are used, one or more cultivations may be accomplished with sweeps attached to the tractor tool bar so as to go between the rows.

TABLE III. SUGGESTED TIME OF SEEDING SORGHUMS

Area	Crop	Month of Seeding
Northern Luzon	Grain, dry	October-November
	Grain, irrigated	October-December
	Forage	May-June or October
	Grass	May-June or October-November
Central Luzon	Grain, dry	October-November
	Grain, irrigated	October-December
	Forage	May-June or October-December
	Grass	May-June or October-December
Western Visayas	Grain, dry	October-November
	Grain, irrigated	October-December
	Forage	May-June or October-December
	Grass	May-June or October-December
Southern Mindanao	Grain	Anytime
	Forage	"
	Grass	"

If rows are sown close together, a rotary hoe may be used one or more times to loosen the surface soil and deter weeds. Except to control weeds, cultivation is usually unnecessary. It is often advantageous to "hill-up" the rows at the last cultivation. This will support the plants and drain excess water away from the plants.

The carabao with some form of toothed harrow may be used when the plants are small to break the crust and kill small weeds. Later, the carabao plow may be used to cultivate between the rows by passing both ways and pushing earth toward the plants leaving a furrow in the middle for drainage.

Water Relations

Dryland - Grain sorghum may be grown in marginal areas where there is insufficient moisture for corn or rice. It may be possible to produce at least a limited crop on moisture stored in the profile with little additional rainfall. Although sorghums have the ability to survive periods of drought and resume growth, they perform best if sufficient moisture is available throughout the growing season.

Irrigation - If the soil is too dry for seeding, irrigate before planting, wetting the soil to a depth of 6 feet or more. It may be necessary to irrigate only two to four times after planting with four inches of water per application. However, the optimum growth of plants will be obtained when the soil moisture is maintained at 50% of carrying capacity. Sorghum plants require the most water at the booting and heading stages. Lodging may be a problem if soil moisture is allowed to become depleted during the filling stage and before the crop is mature. Little water is needed after the grain is in t

dough stage. Excessive moisture at this time encourages head branching and tillering and prevents the plants from drying properly for harvest.

Irrigation may be accomplished with gated pipe in graded furrows by allowing the water to run from the pipe down the row to the opposite end of the field. Irrigation also may be accomplished by flooding or with overhead sprinklers.

Fertilization

An active program of fertilization must be employed. Sorghum is a heavy nitrogen feeder and fertilization will improve production in most situations. As with plants per unit area, the expected level of production should guide the application of fertilizers. Soil tests are recommended for reference. In their absence, probably a complete fertilizer should be used as a basic application with a side-dressing of nitrogen. Table I gives suggested amounts of fertilizer for different levels of yield based on plant requirements. When attempting to produce 5000 kg./ha. of grain, it is suggested that 70 kg./ha. of N, P_2O_5 and K_2O be applied. This can be obtained from 10 bags of 14-14 14. The additional N can be obtained from 2½ bags of urea or 5 bags of ammonium sulphate. Other amounts of fertilizer are suggested for different levels of anticipated production.

All of the fertilizer may be applied before seeding and worked into the soil. It may also be put down just before seeding in a band 5 to 15 cm. underneath and to one side of the seed.

A third alternative and possibly the preferred method of application is to put down the complete fertilizer either before or at the time of seeding, followed by a top-dressing or side-dressing of nitrogen at the time of last cultivation or when the plants are from four to five weeks old. The availability of soil moisture should govern the amount and time of the top-dressing.

Weed Control

Atrazine and propazine are being used in some areas of the United States with success, but not universally so. These herbicides are used as preemergence sprays to prevent the emergence of both broadleaved and grassy weeds. Users should follow directions and precautions given on the labels. 2,4-D has been widely used as an herbicide to kill broadleaved weeds. It must be applied, however, during the vegetative stage of growth and before the booting stage in order to avoid damage to the sorghum. From 0.6 to 0.8 pounds of an ester formulation per hectare will often control the weeds. Caution must be exercised in the use of 2,4-D because it is a very potent material that will kill or damage other crop plants as well as trees and shrubs. On occasion, drift alone has produced serious damage to crops or plants in adjoining fields. Also, spray equipment used with 2,4-D is very difficult to clean sufficiently well to be safe to use with other materials on susceptible plants.

Chemical weed control is not always a satisfactory substitute for clean cultivation.

Insect Control

The insects that attack sorghum in the Philippines have not been completely determined. No doubt there will be many. Insects may cause damage in the soil to seeds, seedlings, and roots. They may attack the above-ground parts of the plant at any stage of development and they may damage the grain in storage. Malathion and sevin are among the insecticides that can be used without adverse effects to the plant. Certain chemicals such as methyl parthion will burn the leaves. Caution needs to be exercised in the use of grain or forage following treatment with a chemical. Residual amounts of the material may be transmitted to meat and milk. Waiting periods indicated by the manufactures label should be observed. Open heads are often less damaged by insects than compact heads.

Some common sorghum insects and measures for their control are listed in Table IV. Some revisions may have been made in USDA recommendations since 1963. For example, malathion cou could probably be substituted for parathion in certain applications.

TABLE IV - SOME COMMON SORGHUM INSECTS AND CONTROLS RECOMMENDED[1]

Insects	Chemical	Min. Days From Last Application to Harvest	Form of Chemical	Dosage Per Ha.	Remarks
		PLANT INSECTS			
Chinch bug, Blissus leucoptetus (Say)	Dieldrin	60	EC	.3 kg	To base of plants
	Toxaphene[2]	28	EC	2.2 kg	
Corn earworm, Heliothis zea (Boddie)	Phosdrin	3	EC	.6 kg	When larvae are small
	Sevin	21 grain 1 forage	WP	1.7 kg	
Corn leaf aphid, Rhopalosiphum maidis (Fitch)	Parathion	15	EC	.3 kg	
Fall armyworm, Laphygma frugiporda	Parathion	12	EC	.6 kg	When larvae are young in heads or leaf whirl
	Sevin	21 grain 1 forage	WP	1.7 kg	
Grasshopers, many species	Dieldrin	40	EC	2.5-5.0 oz.	
	Toxaphene[2]	28	EC	1.1-1.7 kg	
Sugarcane aphid, Aphis sacchari (Zehnt.)	Parathion	15	EC	.3 kg	
Stalk borers, several species	Control depends on killing flights of adults and may be difficult				
Sorghum midge, Contarinia sorghicola (Cog.)	DDT[3]		D	1.4 kg	
Sorgium webworm, Celama sorghiella (Riley)	Phosdrin	3	EC	.6 kg	
	Sevin	21 grain 1 forage	WP	1.7 kg	
Flea beetles	Dieldrin		EC	.4-.6 kg	When plants are small

Insects	Chemical	Min. Days From Last Application to Harvest	Form of Chemical	Dosage Per Ha.	Remarks
		STORED GRAIN INSECTS			
Angoumois grain moth, Sitotroga cerealelia (Oliv.)	Malathion		Dust		Apply as grain goes into storage
Rice weevil, Sitophilus oryza (L.)	Malathion		Dust		Apply as grain goes into storage

(1) Information from insecticidal Recommendations of the Entomology Research Division for the Control of Insects Attacking Crops and Livestock for 1963. USDA Agricultural Handbook No. 120, and from Texas AES Bul. 912 (See references.) Insect species of the United States, in many cases, are different from those found in the Philippines. Therefore, control measures may be different.

(2) Do not feed forage treated with toxaphene to dairy animals or for slaughter.

(3) Do not feed heads or grain that have been treated with DDT.

Disease Control

The diseases that will attack sorghums in the Philippines have not been completely determined. Seed should be treated with a good fungicide such as captan in order to minimize seed rotting organisms, seedling diseases, and loose and covered kernel smuts. For most other diseases, i.e., leaf and stalk diseases, resistant varieties have been the best source of control. Some common sorghum diseases and the suggested control are shown in Table V. Several additional bacterial and fungal organisms are likely to damage sorghum leaves and even stalks, producing lesions and killing tissue. When sorghum tissue is damaged, either by disease or by mechanical injury, the dying tissues become pigmented. The color of the spots depends on the basic plant color, and may vary from purple to red to brown.

Other Hazards

Rodents will crawl up the stems and clip off the grain if allowed to invade the field. Birds will alight on heads and pinch the developing kernels beginning in the milk stage. They will continue to feed on the grain while it matures and after it is ripe. Carabao and cattle will graze on sorghum plants at any stage in their development. They should not be allowed to feed on young plants or on regrowth following clipping or drought because of the danger of prussic acid poisoning. Mature forage or cured forage is considered safe.

TABLE V. COMMON SORGHUM DISEASES AND SUGGESTED METHODS FOR THEIR CONTROL

Disease	Control
Anthracnose *Colletotricum graminicolum* (Ces.) G.W. Wils.	Resistant varieties
Charcoal rot *Sclerotium botaticola*	Resistant varieties
Covered kernel smut *Sphocelotheca sorghi* (LK.) Clint.	Seed treatment
Downy mildew *Sclerospora sorghi*	Resistant varieties
Head smut *Sphacelotheca reiliana*	Resistant varieties
Leaf blight *Helminthosporium* spp.	Resistant varieties
Loose kernel smut *Sphacelotheca cruenta* (Kuhn) Potter	Seed treatment
Rust *Puccinia purpurea* Cke.	Resistant varieties
Stalk rot *Rhizoctonia solani* Kuhn.	Pentachloronitrobenzene (PCNB) 5 kg./ha. dust in row at seeding Field sanitation

SORGHUM GRAIN MANAGEMENT

Harvesting

Harvesting may be done with a combine which cuts off and threshes the heads. The plants may be cut with a binder, shocked, and threshed after hand-heading, or by heading the bundles on the cycle-bar of a combine. Heads with a sufficient length of stalk attached may be threshed by hand with the hampas, hampasan, or flail similar to palay. Heads may be treaded by animals. They may be threshed with a Japanese rice thresher, or with more complicated machines operated by tractors. Sorghum grain will thresh free of the head when the moisture content is 20 to 25 percent. However, the moisture content needs to be low before threshing because sorghum grain does not dry easily. It should be 12 percent or under for safe storage. Varieties with open heads and a dry head-stem often reach a safe storage level sooner than compact heads and green head-stems.

Drying

Sorghum grain may get sufficiently dry for storage while standing in the field, when the environmental conditions are extremely favorable. More likely, the grain will need to be dried either before or after threshing in the sun or with an artificial drier. It must be at or below 12 percent moisture for safe storage. When heated air is used, caution must be exercised not to damage the grain. Maximum temperatures are as follows: for feeding (200°F), for milling (140°F), and for seed (110°F).

Storage

Grain may be stored in treated bags or it may be stored in bulk in wooden or metal bins that have been cleaned and sprayed with an insecticide. The grain needs to be checked periodically for condition. A musty smell or a clumping of the grain will indicate excessive moisture. In this case, the grain may be spread out to dry, it may be aired, or moved to another bin to effect some drying, or it may be mixed with drier grain. Where facilities are available it may be sent to the dryer. Grain sorghum will absorb moisture from a saturated atmosphere.

Fumigation for insect control may be necessary from time to time, and rodents must be kept out.

ESTIMATES OF COSTS AND RETURNS

Table VI shows estimates of production costs and returns for grain sorghum. Using the previous example of 5000 kg./ha., the cost of 6 kgs. of required seed at P6.6/kg. is P40.00. Ten bags of 14-14-14 at P20.00/bag amounts to P200.00. Two and one-half bags of urea at P25.00/bag comes to P67.50. An amount of P225.00 is included for man and animal labor for land preparation, sowing, cultivating, weeding, irrigating, harvesting, threshing, and drying. Total expenses are estimated at P532.50. Gross return from 5000 kg. at P0.20 per kg. comes to P1,000.00, with a net return of P467.50.

TABLE VI. Sorghum Production Costs and Returns (Estimates)

Moisture	Expected Yield		Itemized Cost Estimates in P						Returns in P	
	Cav./Ha. (1)	Kg./Ha.	Seed (2)	Fertilizer (3) 14-14-14	Fertilizer (3) Urea	Fertilizer (3) Total	Labor & Machine (4)	Other (5)	Total Cost	Gross (6)	Net
Rainted Marginal	18	1000	8.00	40.00	12.50	52.00	200		260	200	60
	36	2000	16.00	80.00	25.00	105.00	200		321	400	79
	55	3000	24.00	120.00	37.50	157.00	200		381	600	219
Rainfed Adequate or Partially Irripated	73	4000	32.00	160.00	50.00	210.00	200		442	800	358
	91	5000	40.00	200.00	67.50	267.50	225		532.50	1000	467.50
	109	6000	48.00	240.00	75.00	315.00	225		588	1200	612
	127	7000	55.00	280.00	87.50	367.00	225		647	1400	753
Irrigated	146	8000	63.00	320.00	100.00	420.00	250		733	1600	867
	164	9000	71.00	360.00	112.50	472.00	250		793	1800	1007
	182	10000	79.00	400.00	125.00	525.00	250		854	2000	1146
	200	11000	87.00	440.00	137.50	577.00	275		939	2200	1261
	213	12000	95.00	480.00	150.00	630.00	275		1000	2400	1400

(1) Based on 55 Kg./cavan with 10% moisture content for storage.

(2) Based on need for 1.2 Kg./Ha. of seed @ P6.6/Kg. for each 1000 Kg. of yield.

(3) Based on estimated need for 25 Kg. N + 14 Kg. P_2O5 + 14 Kg. K_2O per hectare for each ton of grain produced, and at a price of P20/50 Kg. bag of 14-14-14 and P25/50 Kg. bag of urea.

(4) Includes land preparation, sowing, cultivating, weeding, irrigating, harvesting, threshing, and drying. This figure will be considerably less if mechanized.

(5) Add in herbicide, insecticide, fungicide, rodenticide, rental, interest, and miscellaneous expenses.

(6) Based on P11 per cavan of 55 Kg. each, or P.20 per Kg. (10% moisture content)

Costs of production if mechanized may be considerably less. However, no cost estimate was included for land rental, interest, insecticide, herbicide, rodenticide, or other miscellaneous expenses.

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February 27, 1967